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Klövviltsbetets påverkan på höjden hos löv- och barrträd samt fältskiktet beroende på årstid – en experimentell studie med säsongsbaserade uthägnader i nyupptagna hyggen

Filip Ånöstam

Examensarbete i ämnet biologi 2017:4
Department of Wildlife, Fish, and Environmental studies
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Abstract

Browsing and grazing by ungulates affect the forest structure by altering species composition and affect the growth in individual trees. The purpose with this study is to investigate the ungulate species composition visiting the clear cut, how timing of browsing affects the height increment in deciduous and conifer saplings, and how deer grazing affects the field layer coverage and height. I used seasonal exclosures in ten clear-cuts where I took data on deer visitation using camera traps, field layer vegetation coverage and height, and also height and browsing pressure on individual saplings. Each site had one permanent exclosure, one exclosure which was closed in winter but open in summer, one exclosure which was open in winter but closed in summer and one control plot which was never fenced off. The majority of the ungulates were fallow deer which shoved a higher visitation rate during summer than winter. Permanent exclosures and exclosure which were closed in summer had the highest height increment for deciduous trees. The difference in field vegetation height between 2015 and 2016 showed an effect of deer visitation rate per site but not for treatment. Browsing during summer lowered the height increment in deciduous saplings compared to winter browsing. It's too early in this experiment to make conclusions on conifers but it seems that the timing is not as important factor as it is for deciduous saplings regarding to height development.

Introduction

Around twenty three million hectare or fifty seven percent of Sweden consist of productive forest, therefore forestry is an important part of our economy (Nilsson et al., 2016). Human activities such as forestry and agriculture have changed the forest structure and ecosystem all around the world, included Sweden (Ostlund et al., 1997). In 1940, clear-cutting started to be common in the Swedish forestry and still is in this time (Ostlund et al., 1997). The clearing of forest and less use of forest as pastures for livestock increased the abundance of deciduous saplings and together with a changed Moose (*Alces alces)* management practice, the Moose population culminated during 1980 after an increase during the 20th century (Fig. 1) (Lavsund et al., 2003, Edenius et al., 2011, Kardell, 2016). As a result of the more dense Moose population, the browsing pressure on the economical valuable Scots pine (*Pinus sylvestris)* increased (Hörnberg, 2001, Lavsund et al., 2003). During the last decades, Fallow deer (*Dama dama)*, Red deer (*Cervus elaphus*) and Wild boar (*Sus scrofa)* have also increased rapidly in southern part of Sweden (Fig. 1). Thus, local areas with high populations of ungulates can therefore get severe damages on crops and forest (Cromsigt et al., 2013).

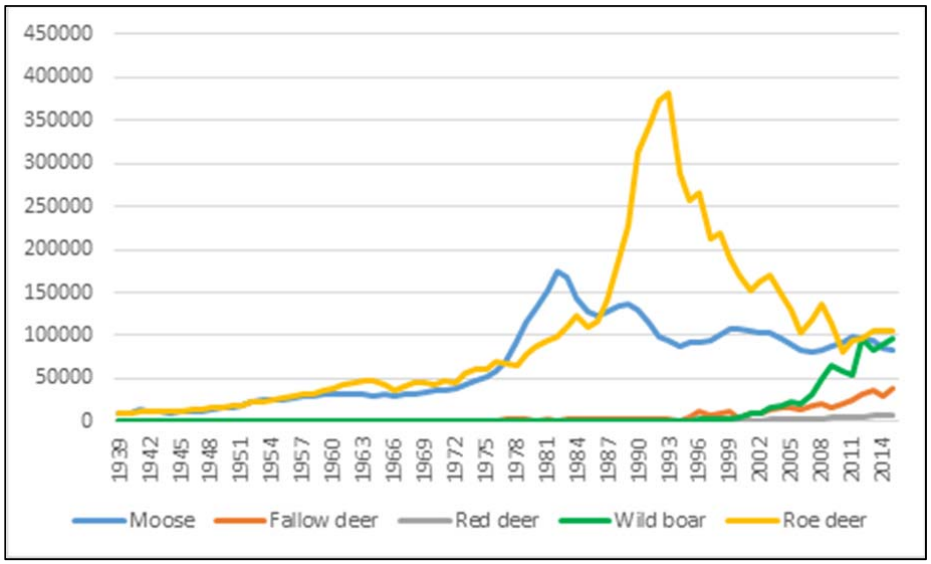

Figure 1: Hunting bag statistic 1939/40 – 2015/16 in Sweden from Swedish Association for Hunting and Wildlife Management for the species Moose (blue), Roe deer (yellow), Red deer (grey), fallow deer (orange) and Wild boar (green).

Our four deer species have different food niches even if it overlaps, e.g., Roe deer (*Capreolus capreolus)* and Moose are concentrate selectors which means that they avoid food that is hard to digest such as grass. Instead, they prefer forbs and leaves from deciduous trees which are easier to digest during the summer (Cederlund and Nystrom, 1981, Hofmann, 1989, Krasnov et al., 2015). In winter, the main food resource comes from shoots on deciduous trees, Scots pine (*Pinus sylvestris*) and for Roe deer also Spruce (*Picea abies*) (Cederlund and Nystrom, 1981). Fallow deer and Red deer are so called intermediate types, which means that they can digest more fibrous food as grass even if they prefer forbs and leaves, i.e. they are opportunistic and can therefore eat what is available in a higher degree than Roe deer and Moose (Hofmann, 1989).

Studies has showed that ungulates affect the forest development both directly through browsing on plants (Bergstrom and Danell, 1987, Bergstrom and Danell, 1995, Den Herder et al., 2004, Den

Herder et al., 2009, Kuijper et al., 2010) and indirect as changing the nutrient levels in the soil (Hobbs, 1996) or alter the inter-specific competition (Tremblay et al., 2007). The direct and indirect effects from herbivory change therefore the forest structure (Schreiner et al., 1996, Rooney and Waller, 2003, Kuijper et al., 2010). The development in seedlings and saplings are affected by many factors and the system are complex, these factors can be the browsing pressure, timing of the browsing and environmental conditions, but also reactions to browsing differs between species (Bergstrom and Danell, 1987, Edenius et al., 1993). Leaf stripping on birch and willow can lower the height increment, which means that the plant stay in height for browsing during a longer time (Bergstrom and Danell, 1995, Den Herder et al., 2004, Den Herder et al., 2009). Heavy simulated winter browsing (100%) on *Betula spp.* shoots reduce the height according to Bergstrom and Danell (1987). In contrast, Den Herder et al. (2009) could also see a compensatory height growth caused by winter browsing on Silver birch (*Betula pendula*). The winter browsing on *Betula spp.* may also result in more and bigger leaves per shoot (Danell et al., 1985). For *Salix caprea*, winter browsing can make the individual more branched (Bergman, 2002). The recruitment and growth of woody species is also affected by the shading, and high coverage of field layer vegetation can lower the possibility for the seedlings to grow (Berkowitz et al., 1995, Nilsson and örlander, 1999, Vandenberghe et al., 2006).

Herbaceous species reacts differently to browsing and tramping, some of them are very sensitive and disappear at high deer densities, whereas others are resistant towards browsing and some can even gain benefits from it (Brunet, 1992, Bowers, 1993, Bergquist et al., 1999). Browsing on herbaceous plants can lower the total coverage (Brunet, 1992), but the total number of species are often not affected (Brunet, 1992, Bergquist et al., 1999) or can even be higher at intermediate disturbance (Bowers, 1993, Schreiner et al., 1996). Still, studies with deer exclosures in Wisconsin showed that high deer population can alter the proportion of species from being dominated by forbs in the exclosures towards domination of graminoids outside the exclosure (Rooney, 2009).

Studies reveal that ungulates often prefer quantity before quality when they foraging, i.e. a high part of the ungulate populations forage out in the gaps where the food availability are high (Kuijper et al., 2009). Browsing on conifers and especially top shoot browsing lower the growth and quality of the timber (Edenius et al., 2002) and as a result, a conflict between stakeholders in how to manage ungulate populations is a fact (Sandstrom et al., 2011). A proper ungulate population management are of importance to maintain ecological, economical and sociological functions in Swedish forest. Due to the reason that the ungulate species has different feeding preference it's important to find knowledge about how the ecosystem is affected in a multi-species community.

Most research that have been done in Sweden on how ungulates affect ecosystem and plant communities have been directed toward single species, e.g. moose (Bergstrom and Danell, 1987, Bergstrom and Danell, 1995, Den Herder et al., 2009), Reindeer (*Rangifer tarandus)* (Olofsson et al., 2001, Olofsson et al., 2004) and Roe deer (Bergquist et al., 2003, Bergquist et al., 2009), but some studies have also looked on Roe deer and Moose (Bergquist et al., 1999, Kullberg and Bergstrom, 2001). Only a few studies in Sweden have looked at how Roe deer and Moose together with Red deer and Fallow deer affect the biodiversity in Sweden (Mansson et al., 2015). It is still unclear how the height growth in tree saplings and forest development is affected depending on the timing of the browsing.

The aim of this study is to use seasonal exclosures and camera traps to study:

1) The ungulate use of clear cuts as a feeding site during winter and summer

2) How the timing of browsing on deciduous trees and conifers in early-stage clear-cuts affects the height increment

3) How vegetation height and coverage are affected by the timing of deer grazing.

I predict that:

1) Deer visitation in the clear-cuts will be higher during summer than winter because of more food available during summer and the supplementary feeding during the winter

2) It will be differences in the height increment depending on the timing of browsing and be lower with increasing vegetation coverage and deer densities

3) The vegetation coverage and height will be affected by ungulate densities and timing of grazing.

Methods

Study Area

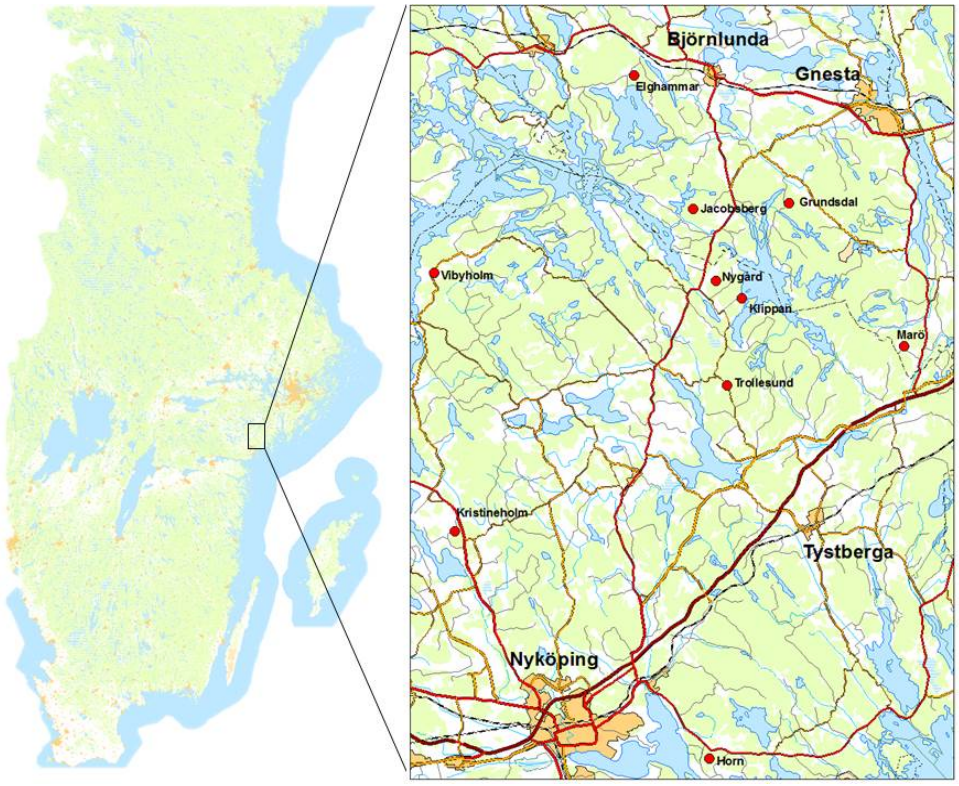

Figure 2: A map that shows where the study area and the sites are located.

The study area is situated in the eastern part of the province Södermanland between Nyköping and Björnlunda (fig. 2). Viable populations of five ungulate species exist here: Fallow deer, Moose, Red deer, Roe deer and Wild boar. According to FOMA (2015), the vast majority of the ungulates is Fallow deer with 88-107 individuals/10km^2, the second most common species is Roe deer with 20-25 individuals/10km^2, the third Red deer with 7-11 individuals/10km^2 and last Moose with 6-10 individuals/10km^2. Ten early-staged clear cuts were selected for the experiment. Four plots (treatments) in each site that could be fenced off were established, by erecting posts in 14 by 14 meter squares in the summer of 2015 (fig. 2). Metal frames were attached to the posts to fence out ungulates, but not smaller mammals such as hares (*Lepus spp.*). One of the four plots was closed during winter (winter treatment), one was closed during summer (summer treatment), a third was closed the whole year (full year treatment) and a fourth was open the whole year as a control. Treatments were assigned randomly to the plots in each site. All clear-cuts were logged in 2014 except for the site Horn which was logged in 2013, and all places have been soil scarified. In all sites, Scots pine or Norway spruce were planted except in Horn were pine was self-sown. The first monitoring was carried out in August 2015 when the project began, in April 2016 when the fence from the winter exclosure were moved to the summer exclosure, in July 2016 in the middle of growing season and the end of September 2016 when the fence from the summer exclosure were moved back to the winter exclosure.

Data collecting

Camera trapping

I used camera traps to examine the ungulate species composition during summer and winter. Camera trapping is a convenient tool for examine the presence of animals and their behaviour (Kuijper et al., 2009). In this project, one camera was recording from the south-eastern corner (corner number one in fig. 3) in all currently open exclosures, i.e. 2 cameras were used in each clear-cut. This made it possible for me to examine the species composition and visitation rate in every site. The cameras were by the models Reconyx HC500 Hyperfire and it were set to take three pictures sequences.

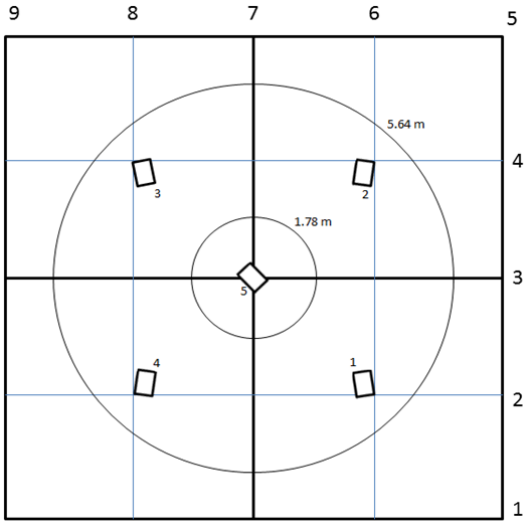

Figure 3: Illustration over an exclosure with the five treatment plots (1. 2. 3. 4. 5) for the field layer and the 1.78m ($10m^2$) and 5.64m ($100m^2$) plot for tree abundance (which I didn't use in this paper). The camera trap is placed in the first corner.

Herbaceous plants and shrubs

I collected data on following groups of species in the field layer vegetation: Grass (*Poaceae spp.),* Sedges (*Cyperaceae spp.*) and Rushes (*Juncaceae spp.*), Forbs, Blueberry (*Vaccinium myrtillus)*, Lingonberry (*Vaccinium vitis-idaea)*, Heather (*Calluna vulgaris*), Raspberry (*Rubus idaeus*), True ferns (*Polypodiopsida*) and Horsetail (*Equisetum spp.*). This was done in five plots in every treatment, one in the middle of every quadrant and one in the middle of the whole exclosure (fig. 3). In each plot, height was measured at the three highest points for every group of species. Next, I estimated the coverage of every single group plus water and soil in following classes: 0%, 0.1-24.9%, 25-49.9%, 50-74.9%, 75-99.9%, 100%. This was done by putting out a grid with a total size of 5x7dm with 35 squares ($1dm^2$) where I estimated the coverage in each cell.

Individual saplings

During the first inventory in 2015, one-year old seedlings/saplings of following species were selected for further measures: Rowan (*Sorbus aucuparia*), Aspen (*Populus tremula*), Salix (*Salix spp.*), Oak (*Quercus robur*), Silver birch (*Betula pendula*), Downy birch (*Betula pubescens*), Scots

pine (*Pinus sylvestris*) and Spruce (*Picea abies*). A maximum of eight individuals (one of each species) were marked in every quadrant, which means maximum 32 seedlings per species in the whole exclosure. Every individual was at least 10cm when I marked it in 2015 and with a maximum age of one year, this criterion was not for the conifers because they were often planted and older than one year. Instead I took the conifer that was closest the middle of every quadrant in the treatment. The data I collected on these individuals was height, number of shoots (>1cm long), number of browsed shoots, if the top shoot was browsed and leaf-stripping.

Data preparation

Camera trap

The metadata (time, date and sequence number was extracted from all 71896 pictures taken during the study into a CSV-file using the free software ExifTool (Harvey, 2003). In every picture I counted the number of animals of each species and noted if they were foraging or not. I defined it as foraging if I could see that the animal had their head down in the ground or browsing from a tree/shrub in at least one of the three photos in the sequence. For the camera trap data, I defined 'deer seconds' as one second when one deer is foraging in one picture e.g. 10 pictures with 10 foraging deer in each are 100 deer seconds. Cameras had been up for different number of days, therefore, I took the number of deer seconds and divided that with the number of days the camera had been recording. The cameras did not cover the same size of area or the same size inside the exclosure and therefore I had to calculate the average number of deer seconds between the exclosures for each site.

Herbaceous plants and shrubs

For the field layer, I calculated the proportion of bare soil. Because I had the coverage in ranges with 25 percent units I assumed that the proportion soil in each square was 0%, 12.5%, 37.5%, 62.5%, 87.5% or 100%. With this data, I estimated the total proportion of bare soil in the exclosure using the formula:

$$Proportion\ Soil = \frac{\sum(X * n)}{175}$$

Where *n* is the number of squares with the assumed proportion soil (*X*), 175 (35x5) represent the total number of squares in each exclosure. In my analysis, I used the average proportion of bare soil during the experiment except from the spring due to missing data. To see the change in vegetation height, I took average height in each exclosure for all groups of species in the field layer and did the same thing for forbs only.

Individual seedlings

The number of days between the monitoring events differed between sites, therefore, I had to correct for that using the formula for annual net increment (Churski et al., 2016). But instead of using per year I used the number of days between first measuring and the last measuring in every site i.e. daily net height increment (DNHI).

$$DNHI = (H_{final} - H_{initial})/Days$$

The $H_{initial}$ is the height of each individual seedling at the first measure in august 2015 and H_{final} is the height at the last measure in September 2016. I used the average DNHI in each exclosure for

each species/group that I wanted to test for: all deciduous saplings together, only deciduous saplings that were not exposed to browsing or leaf stripping, RASO (Rowan, Aspen, Salix and oak), Betula ssp., only the Silver birch and the conifers.

Statistical analysis

All of the statistical analysis and graphs are made in the statistical software program R (Crawley, 2007).

Camera trap

I compared the winter and summer visitation for all ungulates and for only Fallow deer using the nonparametric paired 2-sample test, i.e. the Wilcoxon signed rank-test. I chose this test due to the reason that the distribution for ungulate and fallow deer seconds per site did not follow normal distribution.

Test for differences in increment

I used a general linear model (GLM) to see what influences the DNHI for different groups of tree species. I used an interaction between three predictors: treatment, the average proportion of bare soil during the year and average number of deer second per day and site for each season. All the tests had normal distributed residuals except for RASO with deer seconds during summer (*shapiro-wilkinson test: $P < 0.05$*), Silver birch with deer seconds during winter (*shapiro-wilkinson test: $P < 0.05$*) and for deciduous trees without any documented browsing or leaf stripping (*shapiro-wilkinson test: $P < 0.05$*). To correct for the non-normal residuals, I had to log transform some of the predictors due to the reason that some of the response values was negative and therefore not possible to log transform. For the RASO group I had to log transform deer seconds per site during summer, for Silver birch I had to log transform both deer seconds per site during winter and average proportion of bare soil. For deciduous trees without any browsed individuals, I had to log transform both deer seconds per site during summer and average proportion of bare soil.

Field layer

I also did a general linear model with the change of proportion bare soil between summer 2015 and summer as a response variable with Treatment and deer seconds during summer as predictors. I also tested, with the same predictors, the change in vegetation height and forb height between summer 2015 and summer 2016.

Results

Ungulate visitation

Table A: Species composition in each site during summer season, the values shows the percentage of the total number ungulate seconds. Coefficient of variation (CV) shows the variation in seconds per day between species in each site and between sites for each species.

Site	Moose	Red deer	Fallow deer	Roe deer	Unknown deer	Wild boar	Ungulate seconds	CV
Horn	0.0%	0.0%	46.6%	53.4%	0.0%	0.0%	1.8	155.5
Grundsdal	0.0%	13.0%	75.2%	11.8%	0.0%	0.0%	1.8	176.0

Klippan	0.0%	0.0%	72.1%	27.5%	0.0%	0.4%	2.4	175.8
Elghammar	0.0%	1.0%	82.9%	16.1%	0.0%	0.0%	3.8	198.4
Jacobsberg	2.2%	38.7%	49.0%	7.7%	0.2%	2.2%	7.3	128.7
Nygård	1.5%	8.4%	82.5%	7.6%	0.0%	0.0%	8.7	194.9
Marö	0.0%	3.5%	95.3%	1.3%	0.0%	0.0%	24.4	231.2
Trollesund	0.1%	0.0%	98.6%	1.3%	0.0%	0.0%	27.4	240.8
Kristineholm	0.0%	0.0%	96.3%	3.7%	0.0%	0.0%	34.4	234.2
Vibyholm	0.0%	0.0%	98.5%	1.5%	0.0%	0.0%	89.0	240.5
CV	196.7	189.8	143.0	55.4	216.8	282.3	134.4	

Table B: Species composition in each site during winter season, the values shows the percentage of the total number ungulate seconds. Coefficient of variation (CV) shows the variation in seconds per day between species in each site and between sites for each species.

Site	Moose	Red deer	Fallow deer	Roe deer	Unknown deer	Wild boar	Ungulate seconds	CV
Horn	0.0%	0.0%	35.9%	64.1%	0.0%	0.0%	0.2	163.9
Grundsdal	0.0%	0.0%	22.6%	72.9%	4.6%	0.0%	2.5	173.3
Klippan	0.0%	1.9%	55.4%	10.7%	1.2%	30.8%	2.2	133.3
Elghammar	0.0%	1.5%	76.9%	20.9%	0.0%	0.7%	3.3	183.7
Jacobsberg	0.2%	30.2%	44.9%	24.3%	0.4%	0.0%	6.7	115.3
Nygård	0.0%	0.0%	99.2%	0.6%	0.2%	0.0%	20.1	242.7
Marö	5.0%	0.0%	58.4%	22.0%	14.6%	0.0%	1.1	133.2
Trollesund	0.0%	0.0%	99.1%	0.0%	0.9%	0.0%	9.8	242.2
Kristineholm	0.0%	0.0%	94.8%	5.0%	0.2%	0.0%	19.6	230.0
Vibyholm	0.1%	0.0%	89.1%	9.5%	1.3%	0.0%	2.3	213.9
CV	236.9	301.4	130.4	109.1	99.9	304.0	109.9	

The majority of the ungulates were Fallow deer in almost all sites (table 1). The number of deer seconds between sites during the summer varied from 1.8 to 89.0 ungulate seconds (*mean=20.1; SE=8.1*) with a coefficient of variation (CV) at 134.4 (table 1). The difference between sites during winter had a CV of 109.9 with a range between 20.1 and 0.2 ungulate seconds (Table 2; *mean=6.8; SE=2.23*). The nonparametric Wilcoxon signed rank test showed no difference between summer and winter visitation for the combined ungulate community (*P=0.084*). For fallow deer, the visitation rate was higher during summer (*P=0.027*).

Height increment

Table C: Proportion browsed shots in the open treatments i.e. summer 2015, summer 2016 and autumn 2016 have only data from winter and control treatment, spring 2016 has data only from control and summer treatment.

Species	Number of shoots Summer	Proportion browsed	Number of shoots Spring	Proportion browsed Spring	Number of shoots Summer	Proportion browsed	Number of shoots Autumn	Proportion browsed

	2015	Summer 2015	2016	2016	2016	Summer 2016	2016	Autumn 2016
Rowan	4	0.0%	3	0.0%	21	47.6%	22	45.5%
Aspen	13	7.7%	13	53.9%	70	17.1%	58	41.4%
Salix	36	19.4%	16	25.0%	173	16.2%	172	41.3%
Oak	-	-	-	-	8	0.0%	8	0.0%
Silver birch	104	24.0%	86	37.2%	521	5.0%	479	8.1%
Downy birch	17	11.8%	9	22.2%	123	18.7%	112	28.6%
Spruce	1157	0.0%	1267	0.2%	10704	0.01%	9657	0.2%
Pine	93	0.0%	80	3.8%	1932	0.2%	1613	0.1%

The browsing rate increased for all species during the winter season and decreased during spring and early summer, and increased again in late summer (table 3). Browsing did not only occur in the open treatments, 34.1 percent of the aspens and 12.2 percent of the Salix was browsed during the time between the summer in 2016 and the autumn in 2016. The proportion browsed shoots did not differ between summer and winter treatment for any of the groups when respective is open, i.e. when summer treatment are open during winter and when the winter treatment are open during summer (fig. 4)

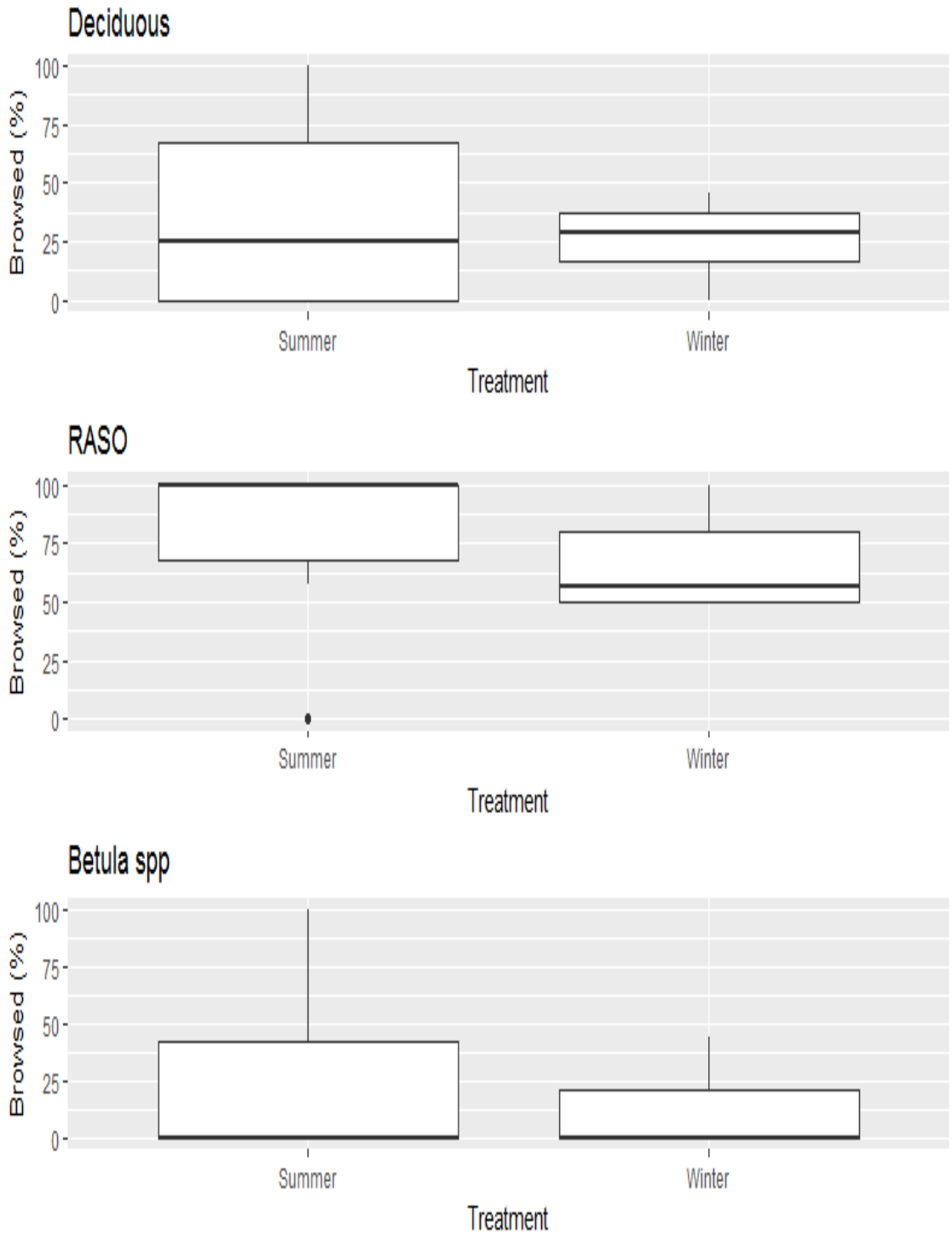

Figure 4: Percentage browsed shoots in summer and winter treatment when respectively is open. The summer treatment represent browsing pressure from the inventory in spring and the winter treatment represent browsing pressure from the inventory in autumn. The data represent only individuals that have been measured both in summer 2015 and autumn 2016.

The DNHI for deciduous saplings was bigger in the summer treatment (*t=2. 953; P=0.006*) and for the full year treatment (t=2.284; P=0.030) compared to the control (Fig. 5). The test with deciduous saplings that had not been documented exposed to browsing and leaf stripping had a trend towards higher DNHI in the summer treatment than in the control treatment (Fig. 5; *t=2.036; P=0.058*). For the RASO group with summer deer seconds, the summer treatment had a higher DNHI than control (fig 5; *t=2.883; P=0.009*). With winter densities I saw a positive effect from the full year treatment compared to the control (*t=2.372; P=0.031*), and a positive effect from deer seconds per site during winter (*t=2.513; P=0.023*). For B*etula spp.*, I could see trending effect toward a higher DNHI in the summer treatment (fig. 5; *t=1.891; P=0.070*) and full year treatment (fig. 5; *t=1.775; P=0.088*) than in the control. The test for silver birch with deer seconds during summer, I could only find a positive effect of the average proportion bare soil (Fig. 6; *t=2,565; P=0.017*). When I tested with deer seconds during winter I could also see a small positive trend with deer seconds *(t=1.805; P=0.086*). It was also an effect on DNHI for deciduous saplings from an interaction between deer second per site during summer and the average proportion bare soil (*t=2.211; P=0.035*), the proportion of bare soil had a positive effect on the DNHI at high deer densities and no effect at low densities.

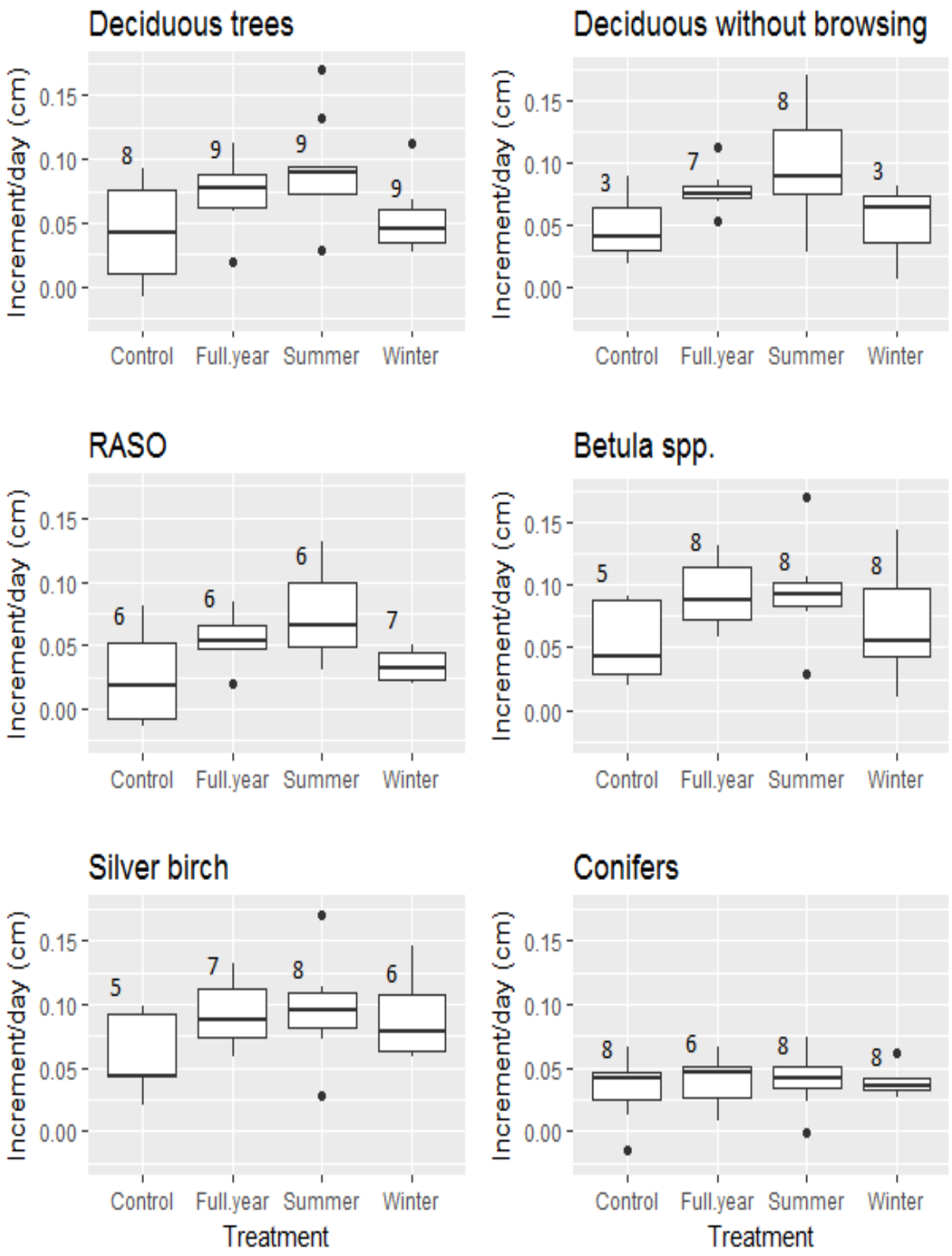

Figure 5: Differences in daily height increment between Treatments for all deciduous saplings, all deciduous saplings that had not been documented exposed too browsing, all RASO saplings, for the Betula spp. saplings, for Silver birch and for the conifers. The numbers over the boxplots represents how many exclosures that had individuals of each group.

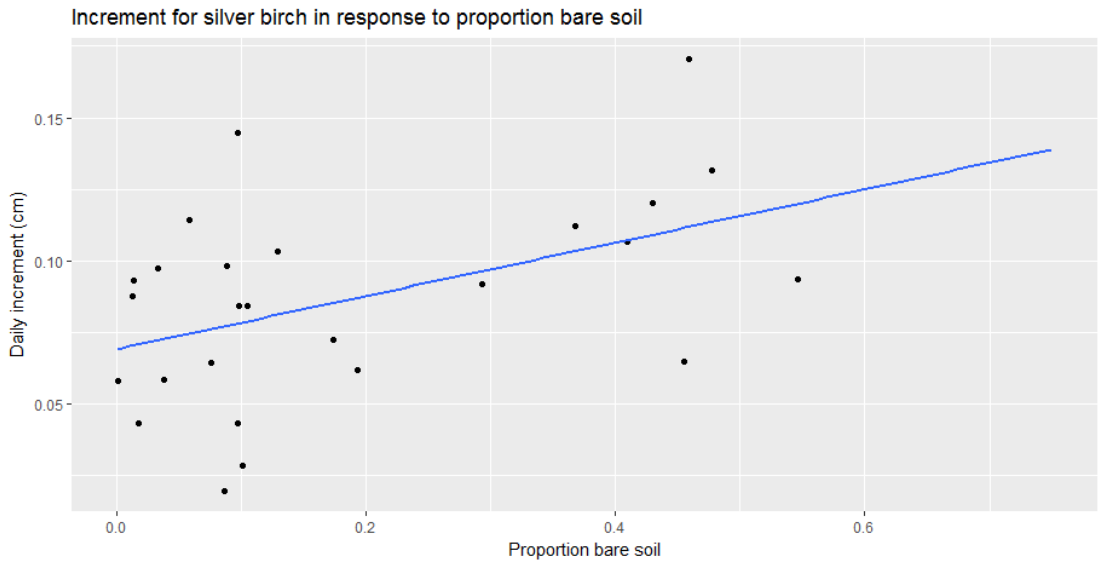

Figure 6: Relationship between the DNHI for Silver birch as a response and the predictor average proportion soil.

The test for conifers with winter densities had a positive response on DNHI from an interaction between winter treatment and Deer seconds (Fig. 7*; t=2.534; P=0.020),* where the open exclosure had a negative effect at higher deer densities. It was also an effect from the interaction between deer seconds and the average proportion bare soil (Fig. 8; *t=-2.307; P=0.032)* where the proportion bare soil had a negative impact at high deer densities.

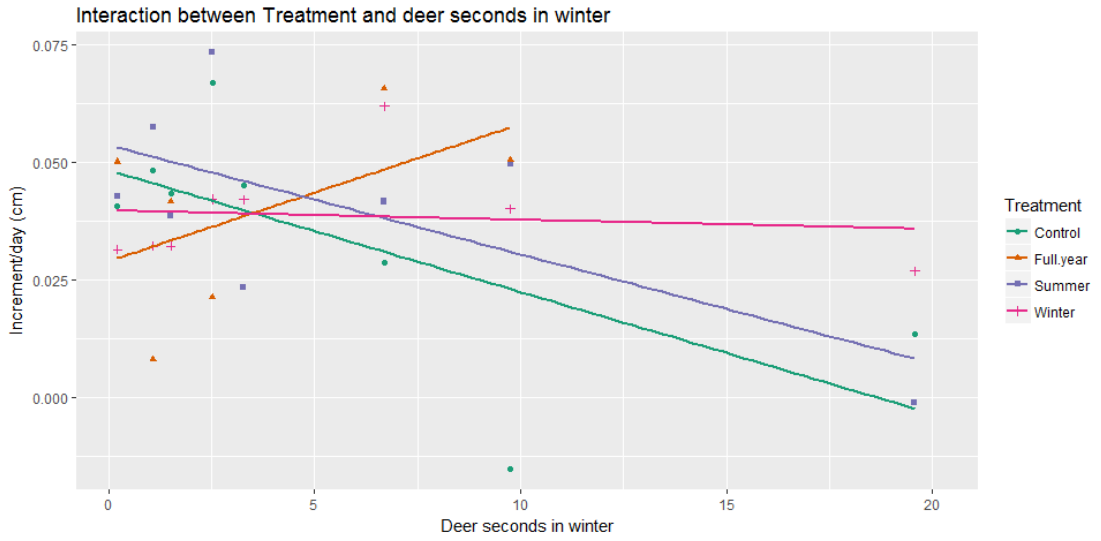

Figure 7: DNHI on conifers as a response to an interaction between treatment and the number of deer seconds per site.

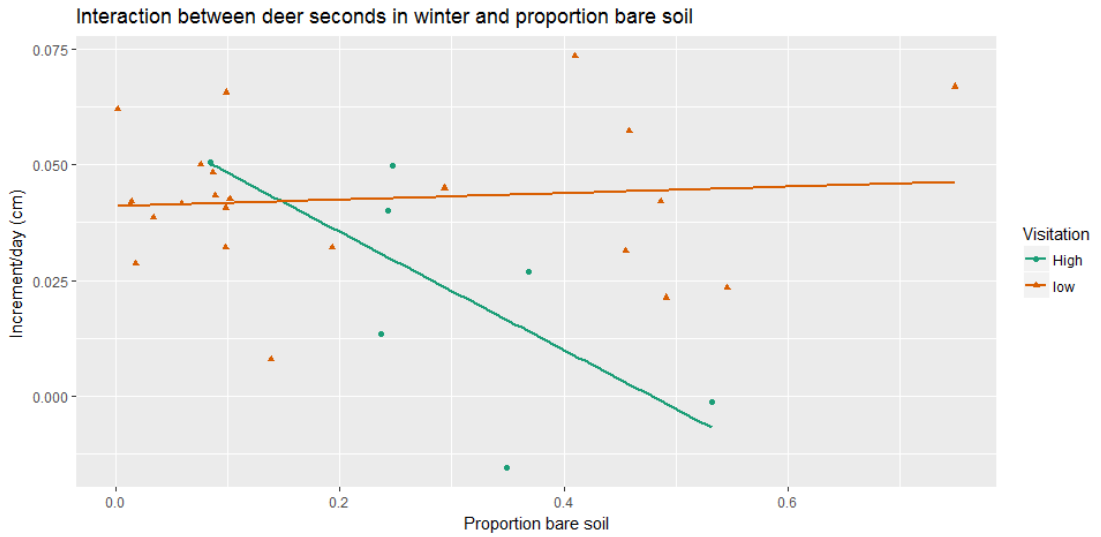

Figure 8: DNHI on conifers as a response to an interaction between proportion bare soil and the number of deer seconds per site converted too high (>7 deer seconds) and low (<7 deer seconds) visitation rate.

Field layer

There was no effect on the change in proportion bare soil between summer 2015 and summer 216. The change in average vegetation height between summer 2015 and summer 2016 had a negative effect from deer seconds during summer (Fig. 9; *t=-3.041; P=0.004*) and the same for average forb height (Fig. 10; *t=-2.799; P=0.008*).

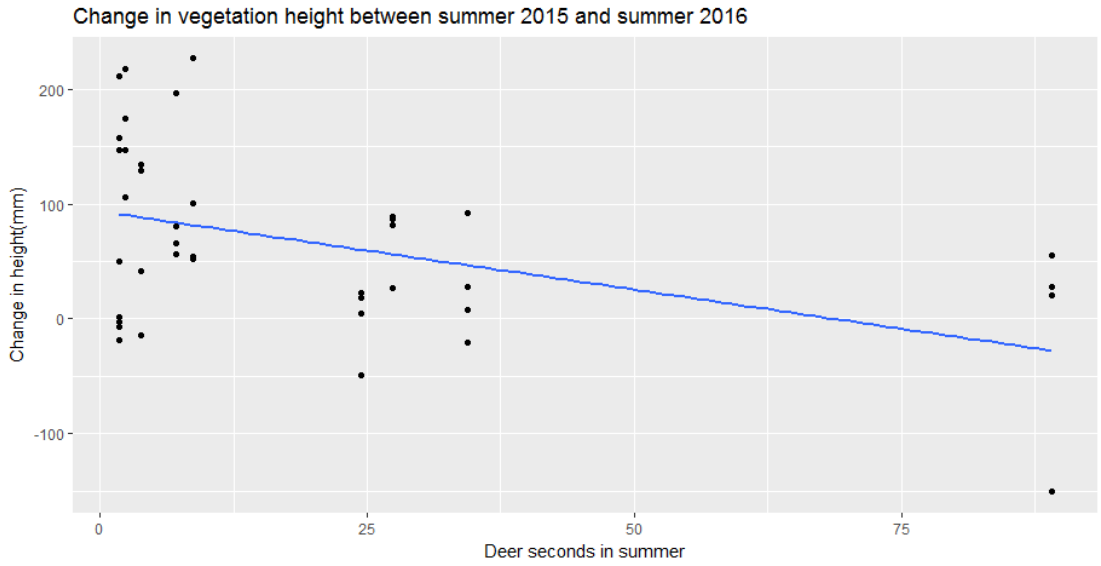

Figure 9: The graph shows a relation between the change in vegetation height between summer 2015 and summer 2016 in relation to deer seconds per site during the summer season.

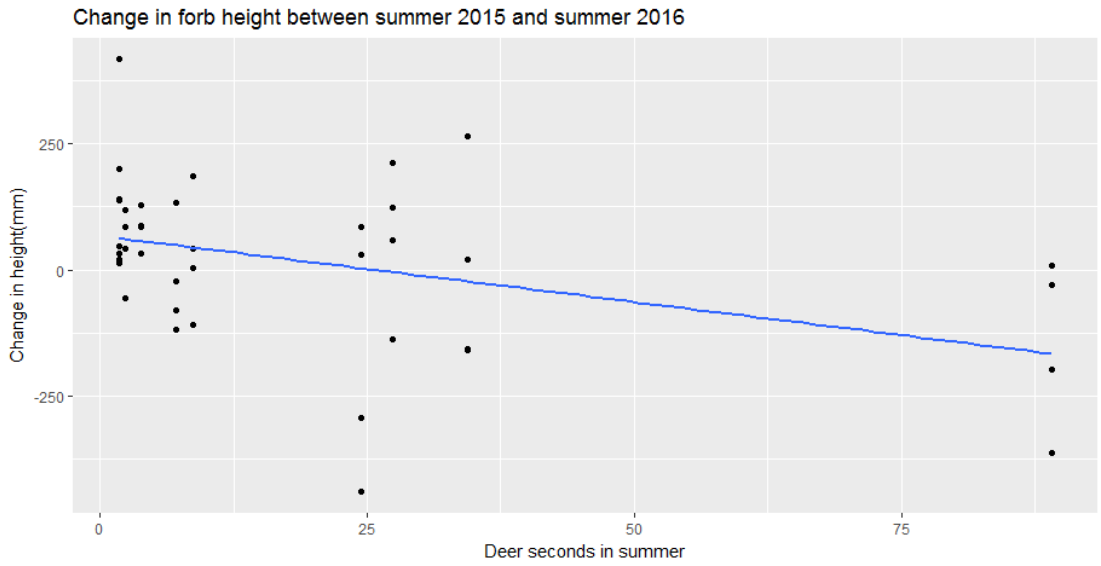

Figure 10: The graph shows a relation between the change in forb height between summer 2015 and summer 2016 in relation to deer seconds per site during the summer season.

Discussion

Ungulate visitation

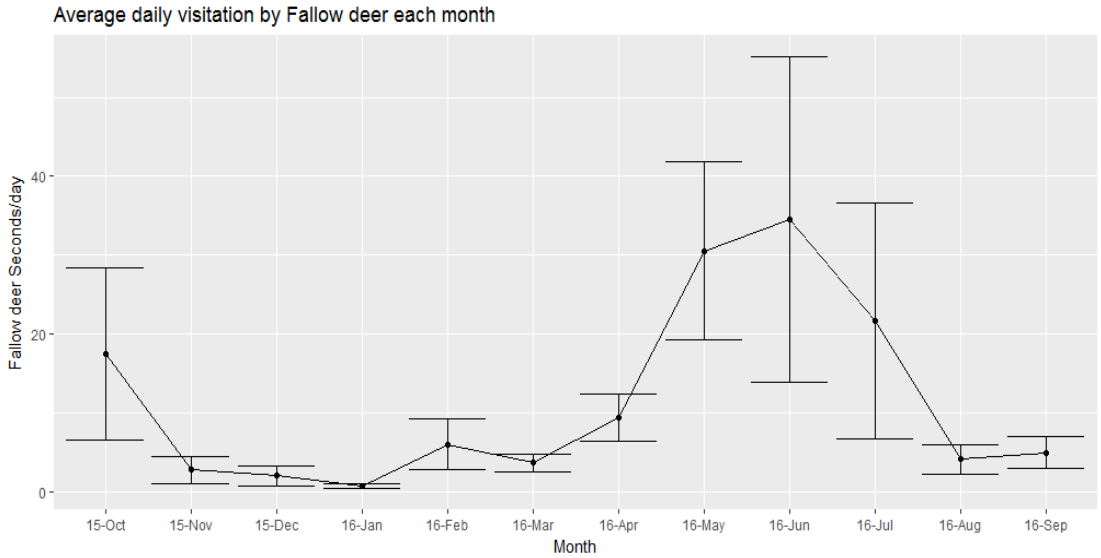

Figure 11: Mean number of seconds per day and month by fallow deer with standard errors. Nygård had a high peak in October 2015 which affects the graph; if the site is excluded, the average visitation was 7 seconds per day.

There was a trend for ungulate visitation rate for ungulates to be higher in summer compared to the winter season; for fallow deer this difference was significant. In one area, Nygård, the visitation rate was higher during winter which could be explained by the high visitation rate during the fallow deer rut in October (Fig. 11). In winter, the natural food resources are lower than in the summer and

therefore the animals gather round supplementary feeding sites (Carlström and Nyman, 2006). During spring the Fallow deer gathers in larger groups at fewer places with high foraging opportunities which can explain the increase in visitation rate in April (Carlström and Nyman, 2006). This is supported by Kuijper et al. (2009); they saw that ungulates preferred to forage in sites with a lot of food which clear-cuts often offer during spring and summer (Kardell, 2016). Variation in visitation is also high between sites and the reasons can be many, first, most of the sites with low visitation rate by Fallow deer had also red deer and a competition of food resources between fallow deer and Red deer may occur (Carlström and Nyman, 2006, Azorit et al., 2012). Second, the Fallow deer are a herd animal and occur often in high densities and therefore they disperse slowly (Carlström and Nyman, 2006). The place where the Fallow deer population in the study area originates is from a hunting enclosure at a mansion close to the site Vibyholm, which can explain the high deer densities at this site. Third, the management practises can be different between sites; some wants the population to be low to protect crops or forest and others want high populations were they can sell high quality hunts.

Browsing pressure

The browsing pressure changed during the period; it increased during winter which means that the woody plants were more important during this time of the year. This is also supported by many scientific papers and it is also well known for Moose and Roe deer (Cederlund and Nystrom, 1981, Krasnov et al., 2015). During the spring and early summer the browsing pressure decreases; at this time the foraging is directed more towards herbaceous plants and also leafs from deciduous trees, at least for Roe deer and Moose (Cederlund and Nystrom, 1981, Hofmann, 1989, Krasnov et al., 2015). During the second half of the summer, I could see again an increase in browsing on deciduous saplings which implies that shoots are also important during summer. This, is supported by a rumen content analysis for fallow deer in the New Forest, England, where they could see that deciduous trees were not an important food resource during winter but a more important one during spring, summer and autumn (Chapman and Chapman, 1997). Instead, the Fallow deer had a higher preference towards eating grasses, conifers, Heather, Bramble and fruits during winter (Chapman and Chapman, 1997). One interesting finding was that I could see a shift in browsing intensity between silver and Downy birch. Silver birch was heavier browsed than downy birch after the winter and this pattern are also supported by Mansson et al. (2007) who could see the Silver birch was more palatable than downy for Moose. However, after the spring I could see a strong shift towards higher browsing intensity on Downy birch than silver birch. More pressure on downy has also been seen in Koberg, where they have high densities of Fallow deer (Mattila and Kjellander, 2017), they did not discuss in the article why the browsing is higher on downy than Silver and I have not found anything about it, but it seems that Silver birch is not more palatable than Downy for Fallow deer. However, this does not explain the shift in pressure and the time will tell how the browsing pressure will develop within the experiment. Still, more surveys needs to be done about the Fallow deer diet in Sweden, e.g. through fecal or rumen sample analysis.

Browsing has not only occurred in the open treatments but also in closed; I could find a high number of Salix and Aspens that has been browsed in the end of summer where around half of them was confirmed browsed by hares or voles. Thus, hares and voles have also an effect on DNHI deciduous saplings.

Height increment

I found that the timing of browsing was an important factor when it comes to DNHI in general for deciduous saplings. The seedlings in treatments that where open in summer had a significant lower DNHI than the ones in the closed treatments. When I divided the deciduous trees into two sub-groups, *Betula spp.* and RASO, I could see that the big difference between treatments was found in the RASO group were it was a significant effect of the summer treatment compared to the control group. However, when I used the model with deer seconds during winter I saw only an effect of full year exclosure although the summer exclosure had a higher DNHI, meaning that this model with winter densities may not be the best model. For *Betula spp.,* I could only see a trend towards higher DNHI in summer and full year exclosure. The browsing pressure did not differ between the summer treatments in spring and the winter treatment in autumn in any of these groups. However, I could not control for how many times individuals were exposed to top shoot browsing, and a difference between seasons can be the case here because of the higher visitation rate in summer. Thus, I cannot exclude that the difference in browsing pressure between seasons makes the DNHI in winter treatment lower than in the summer treatment. However, other studies confirm that when an individual seedling/sapling has been browsed it can increase in height growth as a defence mechanism by growing out of height for browsing (Den Herder et al., 2009, Bergman, 2002). I could not find any effects at all of treatment on silver birch. However, the browsing pressure on Silver birch was much lower than the other species during the summer of 2016. Instead, I could see an effect from the average proportion bare soil for silver birch which suggests that there is competition between field layer vegetation and DNHI; this is supported by other findings that tree seedlings growth is affected by vegetation (Berkowitz et al., 1995, Nilsson and örlander, 1999, Vandenberghe et al., 2006). Individuals that have not been documented exposed to browsing showed no significance between treatments, but a tendency towards higher DNHI in the summer treatment than in the control. The boxplot with individuals that had not been documented exposed to browsing (fig. 5), seemed to follow the same pattern as the other groups of species. However, only three exclosure with one individual in each were not recorded browsed in both control and winter treatment; this can be compared to seven exclosures in the full year and eight exclosures in the summer treatment.

I found an interaction between bare soil and deer seconds during summer on deciduous saplings, which suggests that at high deer densities the effect of proportion bare soil is positive and at low densities it has no effect. However, the two places with the highest DNHI are both summer and full year exclosures, and therefore there is no summer browsing at these places. For the RASO group I could see a positive effect of deer seconds per site during winter opposite to what I expected. This may mean that number of deer seconds in winter had no effect on height increment.

For conifer with deer seconds during winter I found a correlation on DNHI from an interaction between winter treatment and deer seconds. In the control and summer treatment, the DNHI was lower when the densities of deer were high but in the winter treatment the increment were unaffected, and in the full year treatment they were even positive. This is what we could expect; lower DNHI at high deer densities. I could also see an effect from the interaction between deer seconds and bare soil where the proportion bare soil had a negative impact at high deer visitation rate. This can mean that when the amount of food in the field layer is low and the deer densities is high the browsing pressure will increase on the conifers. Due to the fact that top shoot browsing only occurred in one exclosure, and because the growth was so different between sites unrelated to browsing it is important to be careful when making interpretations from these results. However, the exclosure where top shoot browsing occurred had the lowest height increment but the sample size was too low to draw any firm conclusions. Other findings shows that conifers are slow growing

species and may not have the same possibilities to compensate in height as the deciduous trees (Bryant et al., 1983, Ayres et al., 2004).

Field layer

Contrary to what I expected the change in proportion bare soil between summer 2015 and summer 2016 were not affected, either by treatment or deer seconds during summer. However, the experiment has only been going for one year, and therefore it is possible that we will see differences in coverage within a few years. The change in vegetation height for all species and for forb alone was negative affected by deer seconds per site, but not by treatment. It seems that the variation in forb height in 2016 had high variations within sites independent of treatment, the same applies for the total field layer vegetation. This indicates that not only deer densities has an impact on vegetation height but also other factors as moisture, acidity and nutrients availability which is affected by soil characteristic and forest management (Fisher and Binkley, 2000).

Conclusions

The time when browsing occurs is an important factor for the height increment and the development of deciduous seedlings and saplings, especially for the ecological valuable RASO. A high summer browsing pressure on RASO will make it harder for the saplings to grow out of height from deer and become a full grown tree which are of high importance in different ways for many types of species as lichens, invertebrates and even birds and mammals (Carlson et al., 1998, Tikkanen et al., 2006). In an ungulate management perspective, it is important not to just look at deer densities, but also look at food availability and the summer browsing pressure in deciduous saplings. By establish game fields and increase alternative forage availability during the summer the ungulates can be diverted away from the sites susceptible to high browsing pressure. Hunters and foresters have both a responsibility to increase the amount of deciduous trees; foresters should spare RASO in the production sites as a food resource for ungulates, and let tree forming individuals to full grown and hunters need to keep the browsing pressure down by keeping the ungulate populations at sustainable levels.

The results from this project, and especially after it has been going on for a longer period, will give us a better understanding in how the forest is affected by ungulates and how to manage ungulate populations to maintain ecological, economical and sociological functions in the Swedish forest.

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Appendix

Table A: The daily net height increment for each group tested in each exclosure

site	Treatment	Deciduous	Deciduous without browsing	RASO	Betula	Silver birch	Conifer
Elghammar	Summer	0.094	0.094	N/A	0.094	0.094	0.023
Elghammar	Winter	0.068	N/A	0.043	0.093	0.093	0.042
Elghammar	Full year	0.096	0.087	0.048	0.120	0.120	N/A
Elghammar	Control	0.092	N/A	N/A	0.092	0.092	0.045
Grundsdal	Summer	0.089	0.117	0.080	0.107	0.107	0.073
Grundsdal	Full year	0.019	N/A	0.019	N/A	N/A	0.021
Grundsdal	Winter	0.046	N/A	0.046	0.045	N/A	0.042
Grundsdal	Control	N/A	N/A	N/A	N/A	N/A	0.067
Horn	Control	0.043	0.040	N/A	0.043	0.043	0.041
Horn	Full year	0.062	0.053	0.068	0.060	0.065	0.050
Horn	Summer	0.028	0.028	N/A	0.028	0.028	0.043
Horn	Winter	0.054	0.065	0.033	0.065	0.065	0.031
Jacobsberg	Full year	0.072	0.075	0.048	0.084	0.084	0.066
Jacobsberg	Summer	0.074	0.072	0.048	0.100	0.114	0.042
Jacobsberg	Control	0.014	N/A	-0.006	0.029	0.043	0.029
Jacobsberg	Winter	0.034	0.082	0.020	0.044	0.058	0.062
Klippan	Winter	0.061	0.007	0.019	0.145	0.145	0.032
Klippan	Full year	0.089	0.075	0.085	0.092	0.088	0.042
Klippan	Summer	0.072	0.077	0.031	0.092	0.097	0.039
Klippan	Control	0.074	0.089	0.056	0.089	0.098	0.043
Kristineholm	Control	0.080	N/A	0.080	N/A	N/A	0.013
Kristineholm	Full year	0.087	0.070	0.058	0.132	0.132	N/A
Kristineholm	Summer	0.132	N/A	0.132	N/A	N/A	-0.001
Kristineholm	Winter	0.112	N/A	N/A	0.112	0.112	0.027
Marö	Summer	0.170	0.170	N/A	0.170	0.170	0.057
Marö	Winter	0.041	N/A	N/A	0.041	0.062	0.032
Marö	Full year	0.077	0.077	N/A	0.077	N/A	0.008
Marö	Control	-0.002	0.020	-0.014	0.020	0.020	0.048
Nygård	Winter	0.030	N/A	0.050	0.010	N/A	N/A
Nygård	Full year	0.112	0.112	N/A	0.112	0.103	N/A
Nygård	Control	N/A	N/A	N/A	N/A	N/A	N/A
Nygård	Summer	0.095	0.154	0.105	0.080	0.072	N/A
Trollesund	Summer	N/A	N/A	N/A	N/A	N/A	0.050
Trollesund	Winter	N/A	N/A	N/A	N/A	N/A	0.040
Trollesund	Full year	N/A	N/A	N/A	N/A	N/A	0.050
Trollesund	Control	-0.007	N/A	-0.007	N/A	N/A	-0.015
Vibyholm	Full year	0.059	N/A	N/A	0.059	0.059	N/A
Vibyholm	Control	0.042	N/A	0.042	N/A	N/A	N/A
Vibyholm	Winter	0.027	N/A	0.027	N/A	N/A	N/A

Vibyholm	Summer	0.073	0.085	0.051	0.084	0.084	N/A

Table B: Number of individuals of each species in every exclosure

Site	exclosure	Rowan	Aspen	Salix	Oak	Silver birch	Downy birch	Scots Pine	Norwegian spruce
Elghammar	Summer	0	0	0	0	2	0	0	4
Elghammar	Winter	2	0	0	0	2	0	0	2
Elghammar	Full year	1	0	0	0	2	0	0	0
Elghammar	Control	0	0	0	0	5	0	3	0
Grundsdal	Summer	0	2	0	0	1	0	0	4
Grundsdal	Full year	0	1	0	0	0	0	0	4
Grundsdal	Winter	0	2	0	0	0	2	0	3
Grundsdal	Control	0	0	0	0	0	0	0	2
Horn	Control	0	0	0	0	4	0	4	0
Horn	Full year	2	0	0	0	4	1	2	0
Horn	Summer	0	0	0	0	4	0	4	0
Horn	Winter	0	0	2	0	4	0	2	0
Jacobsberg	Full year	1	0	0	0	2	0	0	4
Jacobsberg	Summer	0	1	3	0	3	1	0	4
Jacobsberg	Control	0	0	3	0	2	2	2	4
Jacobsberg	Winter	0	0	4	0	3	3	0	3
Klippan	Winter	1	0	1	0	1	0	0	3
Klippan	Full year	0	1	3	0	3	2	1	3
Klippan	Summer	0	0	1	1	3	1	1	2
Klippan	Control	0	0	4	0	4	1	0	4
Kristineholm	Control	0	1	0	0	0	0	0	2
Kristineholm	Full year	0	2	1	0	2	0	0	0
Kristineholm	Summer	0	1	0	0	0	0	0	2
Kristineholm	Winter	0	0	0	0	1	0	0	2
Marö	Summer	0	0	0	0	3	0	0	4
Marö	Winter	0	0	0	0	3	1	0	2
Marö	Full year	0	0	0	0	0	1	0	4
Marö	Control	0	1	1	0	1	0	0	4
Nygård	Winter	0	1	0	0	0	1	0	0
Nygård	Full year	0	0	0	0	1	2	0	0
Nygård	Control	0	0	0	0	0	0	0	0
Nygård	Summer	0	1	2	0	1	1	0	0
Trollesund	Summer	0	0	0	0	0	0	4	0
Trollesund	Winter	0	0	0	0	0	0	3	0
Trollesund	Full year	0	0	0	0	0	0	4	0
Trollesund	Control	0	0	1	0	0	0	4	0
Vibyholm	Full year	0	0	0	0	1	0	0	0
Vibyholm	Control	0	0	1	0	0	0	0	0

Vibyholm	Winter	0	0	1	0	0	0	0	0
Vibyholm	Summer	0	0	1	0	2	0	0	0

SENASTE UTGIVNA NUMMER

2016:9 Immediate effects on the beetle community after intensive fertilization in young Norway spruce *(Picea abies)* stands
Författare: Martin Johansson

2016:10 Effectiveness of a fish-guiding device for downstream migrating smolts of Atlantic salmon *(Salmo salar L.)* in the River Piteälven, northern Sweden
Författare: Linda Vikström

2016:11 Artificial gap creation and the saproxylic beetle community: The effect of substrate properties on abundance and species richness
Författare: Nils Bodin

2016:12 Extended phenotypes in the canopies of Norway spruce
Författare: Christofer Johansson

2016:13 Comparison of three different indirect methods to evaluate ungulate population densities
Författare: Sabine Pfeffer

2016:14 Estimation of maximum densities of young of the year brown trout, *Salmo trutta*, with the use of environmental factors
Författare: Johanna Wärnsberg

2016:15 Analysis of the successfulness of wolverine (*Gulo gulo*) depredation control in Västerbotten County
Författare: Fredrika Vretling

2016:16 Increased public participation as a potential human – large carnivore conflict mitigation measure
Författare: Ruben Bloemsma

2016:17 Influence of temperature and predation risk on herbivore micro habitat choice in a South African savanna
Författare: Hanna Rogers

2016:18 Elephant utilisation of and impact on a locally threatened habitat, coastal scarp forest, in South Africa
Författare: Matilda Apelqvist

2017:1 Breeding dynamics of a Golden Eagle *(Aquila chrysaetos)* population in the boreal forest of Sweden
Författare: Eirini-Lamprini Daouti

2017:2 Reforestation in the far north – Comparing effects of the native tree species *Betula pubescens* and the non-native *Pinus contorta* in Iceland
Författare: Elin Fries

2017:3 Grazing increases albedo of savanna grasslands
Författare: Linda Vedin